

The background of the entire page is a light gray hexagonal pattern, resembling a honeycomb or molecular structure. The hexagons are arranged in a staggered grid and vary slightly in opacity, creating a subtle 3D effect.

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WHITE PAPER

Smart Cities Run On Smart Power



INTRODUCTION

In the early 1980s, the last of the Baby Boomers entered college. Their favorite music was on vinyl albums and cassette tapes. They received their latest news through newspapers, live television, and radio broadcasts. Free over-the-air radio was the go-to source for most people's news, weather, and traffic information. Cellular phones were just a concept being explored. And personal computers went from being a hobbyist's toy to an essential commercial tool for word processing, running small databases, and doing simple analytics through spreadsheets.

Throughout the 1980s, major cities around the globe experienced the pains of non-stop population growth. By 1990, "Ninety percent of the population growth occurred in metropolitan areas of more than one million people. For the first time, a majority of Americans lived in these large metropolitan areas."¹

Today, 54% of all people globally live within a city's limit, with that figure expected to reach 70% by 2050.² As of 2008, there were more than 400 cities with a population of over 1 million and 19 cities with over 10 million. India, China, and Nigeria are expected to account for 37 percent of the world's urban population growth between 2014 and 2050.

With limited space and resources, modern cities struggle to provide their citizens with the growing quality of life they expect. City planners have resorted to increasing the population density per square kilometer to lessen the need to grow the city limits' boundaries. And they push aggressively to improve the energy efficiency of everything plugged into the city's electrical grid. Streetlamps are migrating from mercury vapor to LED; appliances must be Energy Star[®] rated; offices are required to turn off their lights when not occupied; and, thermostats set to higher temperatures to reduce the energy demands arising from air conditioning systems. The adoption of renewable energy sources is mandated to lessen the need for oil and coal consumption to power the transportation systems and electronic systems of mobile citizens.

Meanwhile, the adoption of electric cars, electric bikes, and other electronic gadgets is placing additional demand on the existing power generation facilities at a rate greater than efficiency programs can offset, requiring supplemental power sources to be brought online. City planners and managers are seeking new ways to change consumption patterns and behaviors of the companies and people occupying the city to make the city more sustainable and more socially equitable.³

EXECUTIVE SUMMARY

A cooperative effort between city governments and private enterprises is leading cities to adopt the goal of becoming “smart cities.” While the definition of a smart city depends on who you ask, the most common understanding seems to be that a smart city provides for the real-time monitoring and control of the infrastructure and services. Thus, smart cities should reduce energy use, reduce pollution, improve public safety, and improve the quality of life for the citizens and visitors.

Smart cities require vast arrays of widely distributed sensors and control devices dispersed throughout their environs. In turn, both wired and wireless networks are deployed to unite the sensors and control systems. These systems gather, store, and process data, and then widely distribute the distilled information quickly to the point(s) where the information can be acted upon or consumed. Edge computing infrastructure handles time-sensitive applications and data aggregation. In contrast, private and public cloud infrastructure provides general-purpose utility computing, big data analysis, and long-term information storage.

In smart cities, remotely managed power distribution provides a means of reducing power consumption, resetting disparate hardware systems, and providing localized environmental monitoring for both the control systems and the networking hardware that make a city “smart.” This paper explores the critical role intelligent power distribution plays in making “smart” happen.

“While (energy) consumption has typically been tied to population growth, a study⁴ (from McKinsey Global Institute) finds that just a quarter of global growth between 2015 and 2030 will come from a rise in the number of consumers. Instead, the great bulk of it will come from their increasing incomes and purchasing power. Large cities will account for 91 percent of consumption growth between 2015 and 2030.”⁵

“As of 2014, midtown Manhattan (New York) used more power daily than did the entire country of Kenya.”⁶ One of the first tools to be deployed by the cities are “smart grids” where electrical meters can be remotely read and have the ability to shed (turn off) excessive loads at times of peak demand.⁷

Reducing energy consumption is only part of the picture for smart cities. Incorporating more renewable energy generation capacity along with a variety of energy storage options is also a key focus of city planners and administrations trying to support the growing energy demand being driven by population growth and the move away from oil dependency on vehicles.



WHAT IS A SMART CITY?

Jack Gold, an analyst at J. Gold Associates, is quoted⁸ as saying that “(a) Smart City is one of those all-encompassing terms that everyone defines however they want.” Gold added, “The ultimate goals of smart cities are power management, reducing pollution footprints, increasing public safety, or offering improved services to residents.”

Wikipedia takes a narrower view when it says, “A smart city is an urban development vision to integrate information and communication technology (ICT) and Internet of Things (IoT) technology in a secure fashion to manage a city’s assets. These assets include local departments’ information systems, schools, libraries, transportation systems, hospitals, power plants, water supply networks, waste management, law enforcement, and other community services.”⁹

For this paper, a smart city is any city that utilizes IoT and networking technologies to manage power, manage traffic, manage resources, and deliver a variety of improved services to its occupants. The smart city may incorporate both edge and cloud computing to handle the large volumes of data generated, processed, and consumed by the city as it operates each day.

TOP 10 SMART CITIES

According to Statista, here are the top worldwide ranked cities in motion, or smart cities. Judged based on the criteria of aiming to give the best quality of life to their citizens using the latest technologies while minimizing the consumption of natural resources and reducing costs.

- | | |
|---------------------|----------------------|
| 1. London | 6. Copenhagen |
| 2. New York | 7. Berlin |
| 3. Paris | 8. Amsterdam |
| 4. Tokyo | 9. Singapore |
| 5. Reykjavik | 10. Hong Kong |

SYSTEMS, SENSORS, AND NETWORKS

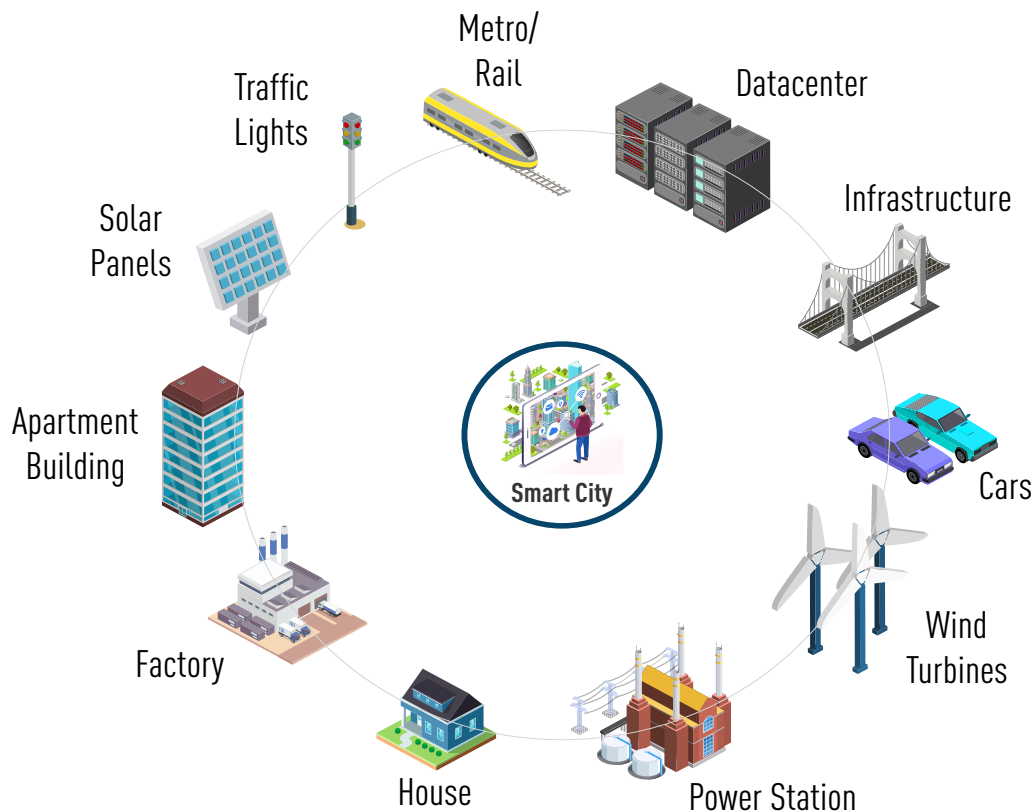
Just as the invention of the silicon transistor led to the development of the integrated circuit, Moore’s law has guided successive generations of chip development to provide even greater functionality in smaller packages that consume less power per operation and cost less per unit. Today’s microprocessors and microcontrollers cost pennies apiece, can be powered by a single cell battery, and deliver wireless connectivity over a wide range of distances and bandwidths. Engineers and Makers¹⁰ alike design these devices into an ever-growing range of applications that provide measurement, monitoring, and control capabilities found in products and services throughout our everyday lives. When combined with the appropriate sensors and power source, these microcontrollers deliver a constant stream of data that can be collected and analyzed to provide actionable intelligence and granular control.

The most common sensor types deployed in smart cities are:

- Electric meters
- Natural gas meters
- Water meters
- Thermostats
- Occupancy sensors
- Touch sensors
- Air quality sensors
- Traffic cameras and pavement sensors
- Security cameras
- Sound sensors (e.g., gunshot detectors)
- Smoke and fire sensors
- Card readers and access controllers
- Rain gauges and anemometers
- Ozone detectors
- Radiation sensors

Recently developed sensors are adding to the wide variety of data available to the cities:

- Building health (accelerometers, strain gauges, tilt sensors that detect settling, wind, and earthquake effects)
- Facial recognition systems
- Parking sensors that identify open parking spaces
- Carbon dioxide and carbon monoxide detectors
- Seismic sensors
- Gutter and street flood detectors
- Flow rate sensors (inside individual pipes)
- Trash and recycling bin status sensors
- Proximity detectors
- Crosswalk activity sensors
- Metal detectors
- Pressure sensors



Sensor data is of little value for most purposes until it is gathered, processed, disseminated, and utilized. The “smart” in the smart city moniker refers to what happens with the data that comes from the city’s sensors. For the citizens in the smart city, this means useful applications and information that lead to convenience.

CONTROL

- Traffic signs to re-route traffic, warn of accidents flooding, etc.
- Traffic signs that automatically update with “time to destination” information
- Traffic flow data is sent to Google, Apple, Waze, and city management applications to suggest alternate routing
- Maintenance/dispatch notices sent to trigger garbage pickup, bathroom cleaning, pipeline maintenance
- Dispatch of emergency personnel for firefighting, shots fired, traffic accidents, road repair
- Automated pickup of garbage, recyclables, and yard wastes (sensors on the street to tell that containers are present and waiting for pickup)
- Turn on streetlights at various times and conditions
- Crosswalk monitoring/change of traffic signals/ crosswalk flashers
- Monitoring public pool chemistry and support systems
- Re-routing internet traffic in the event a fiber or cable has been cut
- Coordinating aerial drone traffic routing
- Building health monitoring
- Scheduling of irrigation systems for sidewalk plants, parks, and other common green spaces
- Sharing of data for educational and research purposes
- Turning off non-critical systems at schools and other public buildings during times when they are not in use

APPS

- Transportation guidance for pedestrians, cyclists, car drivers, bus, and train riders
- Coordination of ridesharing and vanpooling
- Traffic alerts, wind alerts, air quality alerts, water quality alerts, and shots fired warnings are sent to smartphones
- Display proximity to public drinking fountains, restrooms, and other facilities
- Directions to nearest ATM, subway station, bus station, etc.
- Smartphone apps that show parking space availability and reservation systems
- Vehicle charging system location, availability, and reservation systems
- Access control to public restrooms
- Paying city bills
- Voting
 - Reporting violations of rules and regulations
 - Augmented and virtual reality applications for guided tours, guided repairs, and the like
- API interface to natural language interfaces such as Alexa, Cortana, Siri, and Google Now

UTILITIES

- Electric meter system monitoring/billing/control
- Fresh water system monitoring/billing/control
- Wastewater system monitoring/billing/control
- Natural Gas system monitoring/billing/control

Sensors report back to monitoring and control systems through a variety of networking technologies such as:

- RFID
- NFC
- Bluetooth and Bluetooth Low Energy (BLE)
- ZigBee
- LoRA and LowPAN / 802.15.4
- Wi-Fi
- Ethernet LAN/MAN//WAN
- Fiber optic
- Broadband over power line (BPL)
- 4G/5G cellular

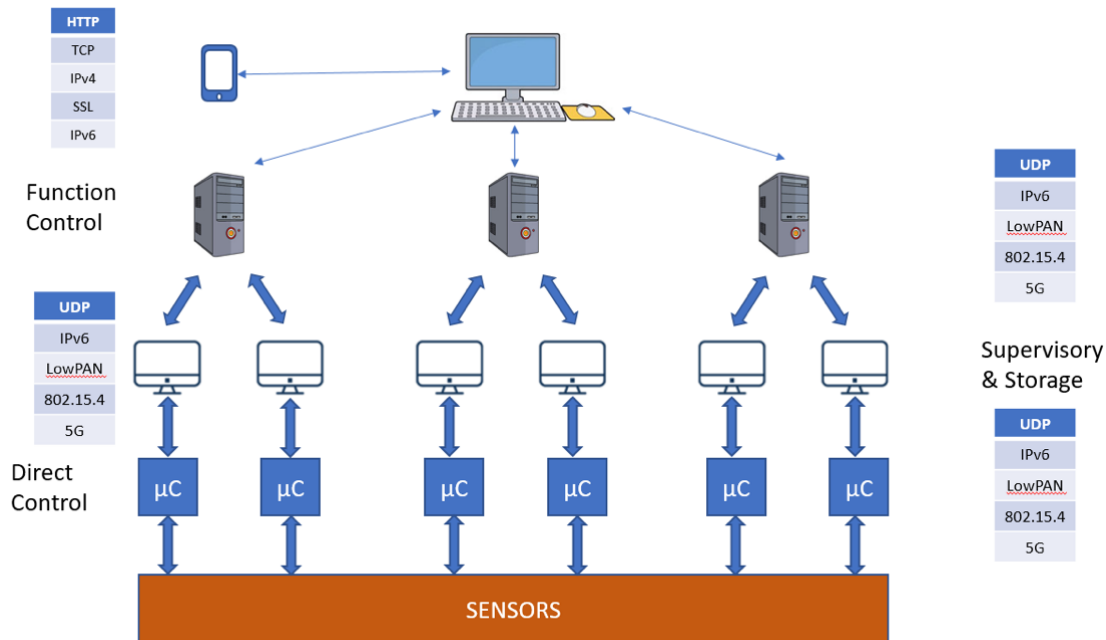


Figure 2: IoT Data Collection

Future sensor connectivity may come in the form of wireless networks using a variety of protocols:

- Li-Fi
- LTE-U
- LAA (Licensed Assisted Access)
- MultiFire¹¹

Frequently these networking technologies require gateways, switches, or routers to be in proximity to the deployed sensors. Depending upon the application, some of the sensors may be deployed in a time-sensitive control application.

This means they may be distributed throughout the urban environment, in edge or fog computing deployments. The systems operate unattended by local human supervisors. In that case, they frequently report through the network to central monitoring points (NOCs, or network operations centers). A macro view of the data coming from the networks may also go to a cloud facility for long-term storage and analysis. For example, meter readings, traffic data, etc., may all be processed by “big data” or “AI” applications looking for patterns, trends, and the like.

Federal regulations may require that some data be summarized and reported to the national level. For example, water usage, water quality, power usage, and the like are all up at the Environmental Protection Agency (EPA). Population data and trends go to the Census bureau. Crime data goes to the FBI. Temperature and precipitation data go to the National Weather Service.

With the prevalence of Application Program Interfaces (APIs) and other data interchange standards, there is no need for a human to be involved in the review chain before data is passed along. The local gateways and databases can communicate directly with their federal counterparts to keep systems up to date in real-time.

THE ROLE OF THE CITIZEN SENSOR

Data surrounds every individual today. Some of it is deliberately generated (selfies, videos, phone calls), and some is collected from the individual (heartbeat data, steps taken, location, websites visited, goods and services purchased) whether they are conscious of it or not. The personal fitness tracker and the ubiquitous smartphone combine to produce much of the data, with the smartphone

providing the majority. And more than 75 percent of the world's population today carries a smartphone. Smartphones represent the single largest source of data on what is going on with people globally.

The typical smartphone has accelerometers, light sensors, cameras, microphones, GPS, and a magnetometer/compass. Communications into and out of the smartphone via Wi-Fi, Bluetooth, NFC, and cellular radios. Applications of many varieties collect both the sensor data and metadata. For example, the Facebook app may be used to share a photograph with friends, family, and followers. But that photograph also carries information about the date and time it was taken and may also have GPS coordinates. If the photographic image contains a face, an algorithm running at a Facebook data center will also perform facial recognition and tag the friends present in the photo.

THE CITIZEN SENSOR - AN URBAN CYBORG

Openly sharing the data from a smartphone helps populate navigation systems with real-time traffic information (speed, traffic jams). It also can be used to monitor the condition of the roads themselves – to automatically make note of pothole locations (a sharp jolt on the accelerometer), for example.



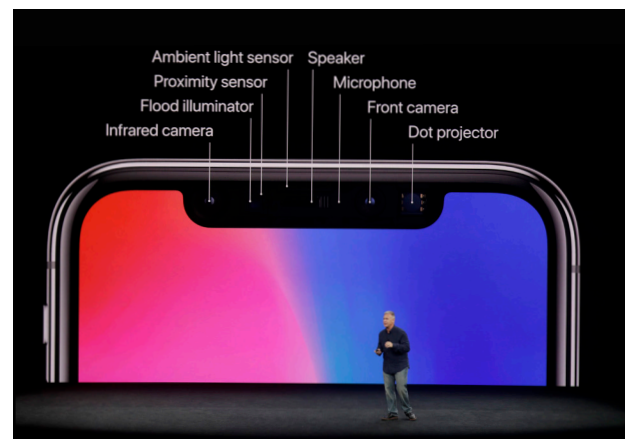


But smartphones are not the only tools that collect the information that defines your existence. A visit to the doctor generates a flood of data pouring into an electronic health records (EHR) system. This, in turn, leads to billing systems and insurance systems. When you are at home, your television watching habits may be monitored by your cable provider or streaming service. Your electric meter tracks your appliance usage. Your telephone knows who you have spoken with, your thermostat tells if you are home and what room you occupy. Your doorbell knows when someone approaches the entry to your home and automatically opens the lock for you and the people you designate for authorized access. Spotify knows the music you prefer. And, Apple knows the podcasts you listen to and where your photos are taken.

POWERING THE SENSORS, SYSTEMS, AND NETWORKS

Beyond the sensors that we carry with us in our battery-powered phones, the smart city sensors are deployed in a wide variety of locations. Car presence detectors are on the pavement of the roads and parking garages. Crosswalk presence detectors. Light sensors in the streetlights. Utility meters on the homes, offices, and factories. Thermometers, ozone detectors, radiation detectors, and smoke detectors may be combined into a “weather station” found on light poles and rooftops throughout a city. Cameras and ultrasonic sensors may be located at street intersections to detect vehicles and adjust

the timing of the stoplights based on demand. Stoplight control systems are frequently found nearby in outdoor enclosures. See Table 1. Local power generation by solar cells and fuel cells will support those sensors that are not near utility power or where the city prefers not to have these loads present on the grid. See Table 1. As previously noted, getting data from these disparate sensors requires a variety of connectivity solutions to get data from the sensor to a point where it can be processed, analyzed, and stored.



▲ Figure 3: Apple iPhone Sensors¹³

“Smart cities use technology to assist their residents, and data is a byproduct of that effort. But who owns the data and how it’s used is up for debate, and it often depends on where you live.”¹²



Power Grid	Solar
Utility Meters	Weather Stations
Buildings	Flood Monitors
Street Lights	Irrigation System Monitors
Traffic Signals	Trash and Recycling Container Monitors
Parking Sensors	5G Linked Sensors
Surveillance Systems	Highway Monitors
Crosswalk Sensors	Mesh Wi-Fi Access Points
Access Card Readers	

Table 1

Legrand in the Smart City

- POE (Power Over Ethernet)
- Intelligent Lighting
- Occupancy Sensors
- Environmental Sensors
- Access Control
- KVM for Remote System Access
- Remote Power Management
- Eliot - Electricity and IoT
- Legrand brands include On-Q, Nuvo, Racklink, Luxul, WattStopper, Intuity, Raritan, Server Technology, Middle Atlantic, Pass & Seymour

The case for remote power management in the smart city infrastructure

With the growing number of sensors and systems deployed throughout the smart city, it means that city staffers must oversee the installation, maintenance, and operation of more products in more locations. Frequently the city employees rely on manufacturers to provide support. When a city the size of Tokyo, Los Angeles, or Houston implements thousands, or even millions, of sensors, sending a person to troubleshoot every fault becomes both time-consuming and cost prohibitive. Having the ability to reset the failing sensor remotely or automatically, device, controlling

equipment, or network makes good sense. It saves both time and money by avoiding the cost of dispatching a person and a vehicle to a remote location to “hit the reset switch.”

Numerous city-managed systems are deemed “too critical to fail.” Priority is given to traffic control signals, for example, due to the potential for lethal impact whenever traffic lights go out. Freshwater pumping stations are another application that has an immediate effect when they go down. Repeater stations used by first responders to provide dispatch and emergency digital communications are crucial to maintaining ambulance, fire, and law enforcement services. However, getting a service person on-site whenever these systems have glitched, frozen, or otherwise gone offline may not be practical. Timeliness is essential and having the ability of the city’s central monitoring point to remotely reset the failing hardware can dramatically improve the perception by the city’s populace that the city is “on top of things.”

“... if an entire city has an “operating system”, what happens when it goes wrong?”

The one thing that is certain about software is that it crashes. The smart city, according to Hollis, is really just a “perpetual beta city”.

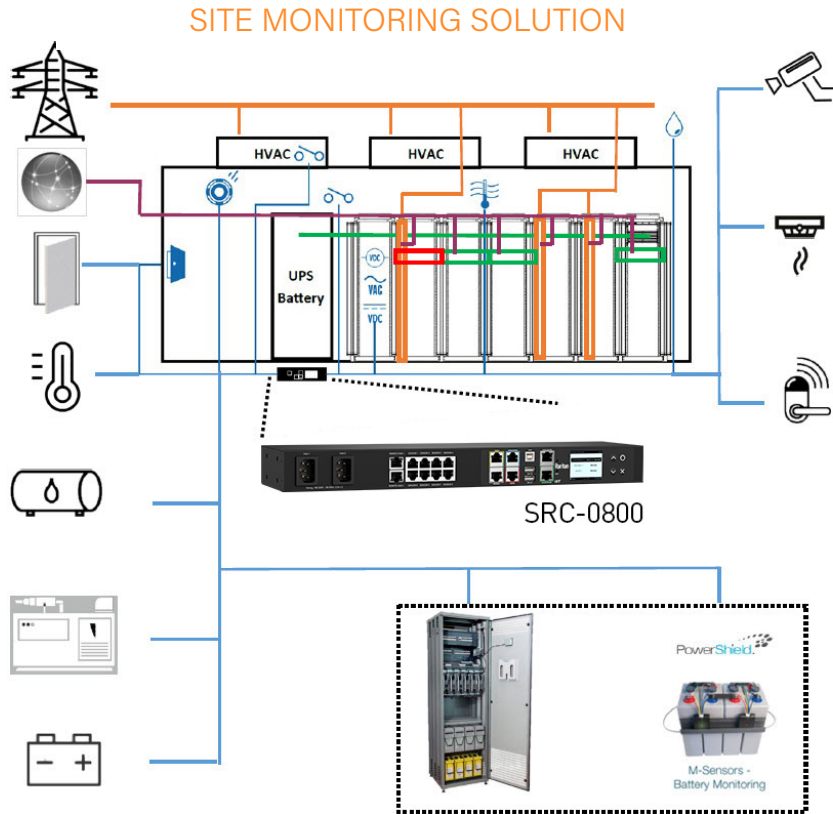
Steven Poole, theguardian.com

As the first line of defense, remote monitoring of the power being supplied to sensors, gateways, and control systems is a “must-have” for ensuring system uptime and reliability. Depending on the application, gateways and control systems may be located on shelters (huts), on rooftops, in NEMA enclosures, or within IDFs within a nearby building. The Smart Rack Controller (SRC) family of intelligent sensor management devices from Raritan, a brand of Legrand, are ideal solutions where monitoring of systems is all that is required. SRC units support remote monitoring of doors, IP-based cameras, environmental sensors for temperature, humidity, smoke, floor mount leak detectors, and air pressure. They can also interface to card-controlled rack and door locks for remote access control. Through a partnership with PowerShield, the Raritan SRC can provide data on lead-acid batteries used as UPS and standby power applications like those found in telecom infrastructure.

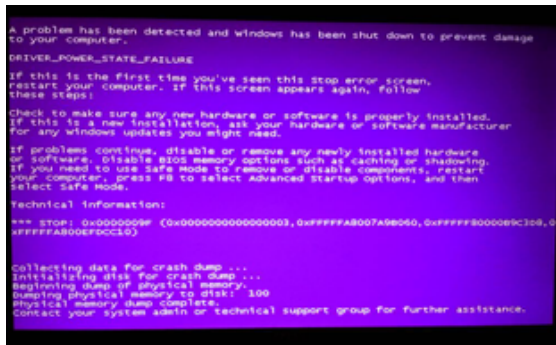




LEGRAND PRODUCTS	
Monitored Sensor	— Blue line
KVM	— Red line
DC Power and PDU	— Green line
AC Power and PDU	— Orange line
Racks & Cabinets	— Black line
Fiber & Copper Connectivity	— Purple line



Displays like the one pictured in Figure 5 below are standard airports and train stations where status screens are frequently left on around the clock, and the systems driving the displays may be located remotely or even off-site from the display. An intelligent rack PDU with switching capability (remotely managed) can help reset the systems that drive this display.



Using network-accessible remotely monitored and managed rack PDUs can help bring the stoplight systems up in the proper order and monitor the temperature and environmental conditions within the cabinet or enclosure housing the stoplight controllers. And detect whether a vandal has opened the doors to the cabinet by detecting the status of dry contact closures. Having an infrastructure powered by intelligent PDUs also provides a path to reduced energy expenditures by turning off assets that do not need to remain on when they are not in use. For example, city buildings such as libraries, schools, and museums can all be powered down when not in use, saving money and being “greener” for the environment.

◀ Figure 5: Frozen Airport Display

Whether your infrastructure is AC-powered or DC-powered, there are Legrand rack power distribution units available from Server Technology or Raritan that are suited to your application. We offer remotely managed intelligent power products capable of supporting loads up to 100kW. And if you require something truly unique, we offer custom rack PDUs built to your requirements.

Figure 6 is a Server Technology -48VDC PDU that offers remote power measurement and remote power switching for up to 15kW of power.



▲ Figure 6: Server Technology -48VDC PDU

Also available is a wide variety of Server Technology 1U and 2U PDUs suited to most small cabinet applications where remote power monitoring and outlet switching are needed. Figure 7 below shows the Server Technology patented High Density Outlet Technology (HDOT) which addresses density challenges by fitting more outlets in a chassis than standard PDU configurations. We've removed the shells around the individual outlets and used module grouping to fit more outlets into the same space. Without the outlet shell, airflow throughout the cabinet is also improved, preventing overheating. Not pictured are ports for ethernet, temperature, and humidity probes.



▲ Figure 7: Server Technology 208V AC PDU

Other Server Technology AC PDUs offer our latest innovation, the HDOT Cx Outlet. The HDOT Cx outlet is suitable for replacing both C13 and C19 outlets in most applications. See Figure 8.



▲ Figure 8: Server Technology HDOT Cx Outlets

The Raritan brand of rack PDUs features the Xerus Technology Platform and our top-of-the-line NIC for state-of-the-art usability, reliability, and flexibility. They also provide the industry's widest range of designs above 10kW, including rack PDUs rated up to 68kW, allowing you to design enough headroom for both today and tomorrow's most demanding compute densities.

Intelligent power products require mission-critical connectivity to maximize their usefulness. This is where working with Legrand makes your life easier because Legrand brings together more of what it takes to keep your Smart City running smoothly with a full range of the highest quality, most reliable connectivity infrastructure in the industry.

Legrand offers fiber and copper connectivity through their Ortronics and Quiktron brands. We also offer rack systems, cabinets, cable raceways, cooling and containment solutions for your most demanding applications.

CONCLUSION

Smart Cities take advantage of the power of harnessing data to make day-to-day living comfortable, convenient, and efficient. They seek to help their citizens achieve meaningful, exciting lives rather than implementing technology for its' own sake. Putting information and services in the hands of the population gives the citizens a sense of participation and belonging to the community while concurrently enabling the city administrators to run the systems that keep the trains, planes, and buses on time, the traffic moving, and the utilities up and running. "Anticipated benefits of smart city solutions include cost savings from operational efficiencies; optimizing use of resources; improved government services and interaction for citizens; (providing a) better stream of data to improve decision-making; and the opportunity to attract tech-savvy workers and businesses."

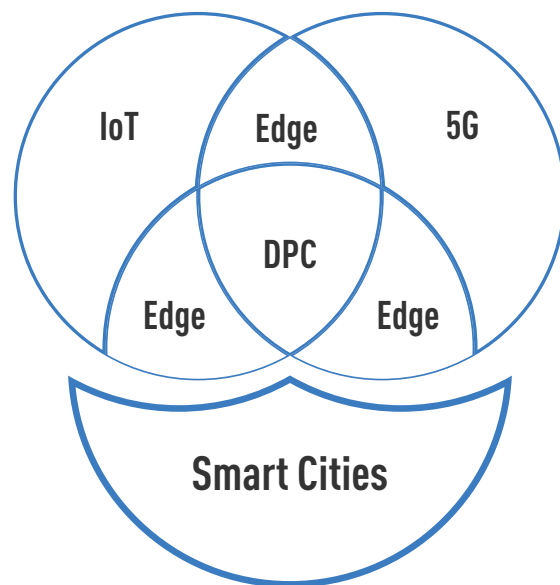
"The next phase of smart cities growth will be contingent on expanding the depth and breadth of expertise among government IT staff and, as challenging as it may be, to expand their workforce," said Tim Herbert, senior vice president, research and market intelligence, CompTIA.¹⁴

With the breadth of sensors (IoT), systems (edge computing), and networks (5G) that go into making the Smart City "smart," it is imperative that the architects and designers provide an efficient means of remotely monitoring and resetting the underlying hardware to minimize downtime, avoid costly truck rolls, and ensure the satisfaction of the citizens relying on the use of those systems. Working with trusted partners that are Power Strategy Experts such as the Raritan and Server Technology brands of Legrand to power the sensors, systems, and city's network is just plain smart.

10 STEPS TO A SMART CITY

1. Strong public-private partnerships
2. Data openness and third-party collaboration
3. User-first information resources for public services
4. Free, citywide internet connectivity
5. Smart kiosks
6. Smart public transport
7. Getting smart on public safety
8. Green, sustainable solutions
9. Digital voting systems
10. Prepare for autonomous vehicles and the sharing economy

Source: Smart Cities Summit



WHY SERVER TECHNOLOGY

Server Technology's power strategy experts have provided power solutions for labs, data centers, branch offices, and telecommunications operations for 30 years. Over 60,000 customers around the world rely on our cabinet power distribution units and award-winning power management solutions to reduce downtime, facilitate capacity planning, improve energy utilization, and drive efficiency. With the best quality, best technical support, and most patents, Server Technology products provide uncompromising reliability, innovation, and value for the data center.

Only with Server Technology will customers Stay Powered, Be Supported and Get Ahead.

WHY RARITAN

Raritan, a brand of Legrand, delivers more than 30 years of innovation and experience from the data center market to your IoT and smart city network operations centers. Our products remotely monitor every critical aspect of your gateways and edge data centers:

- Remote Access & Control to Reduce On-site Maintenance
- AC & DC Power Management
- Technology Extensions to Virtually Any Internal Applications with our Xerus Platform

See for yourself how Raritan can help you reliably deliver power, access, and control for your smart city applications.

WHY LEGRAND

At Legrand, we deliver access to power, light, and data to millions of spaces around the world. Learn more at www.legrand.us

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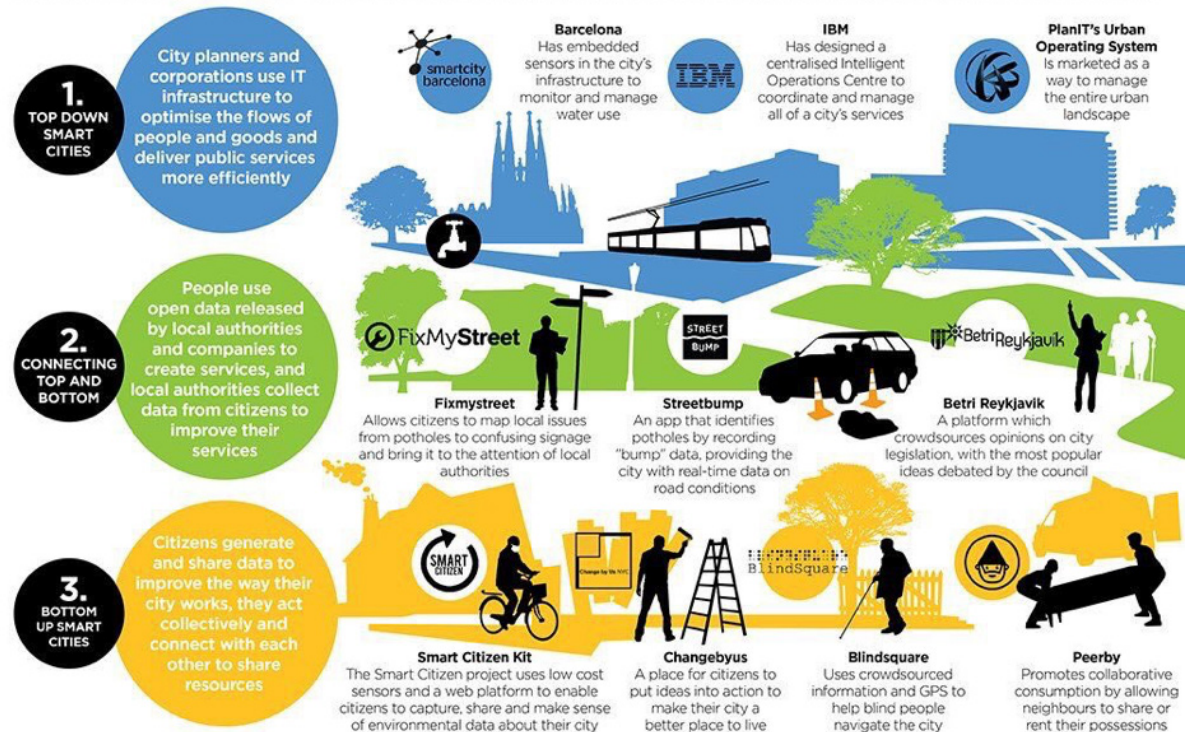
APPENDIX 1: ROADMAP FOR DEVELOPMENT OF A SMART CITY



http://www.academia.edu/21181336/Smart_City_Roadmap

SMARTER SMART CITIES

The "smart cities" agenda is mainly focused on top down technological initiatives (embedded sensors, data integration and analytics). The real smart cities of the future will mobilise human intelligence as well as artificial intelligence, bottom up creativity as well as top down control.

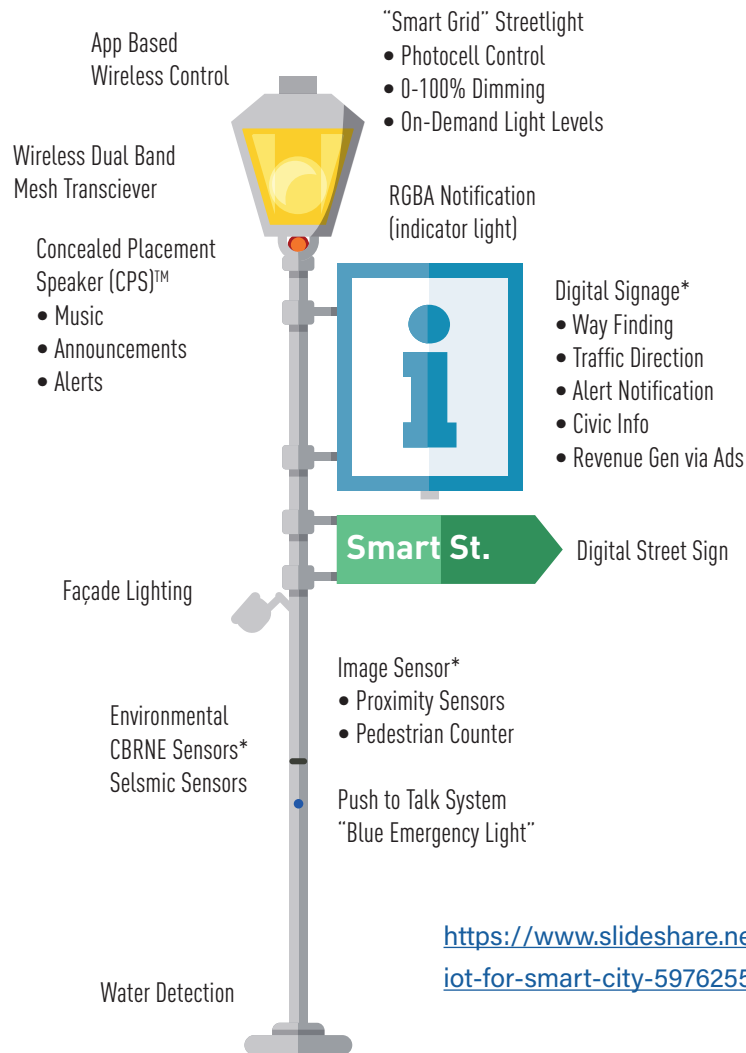


http://www.academia.edu/21181336/Smart_City_Roadmap

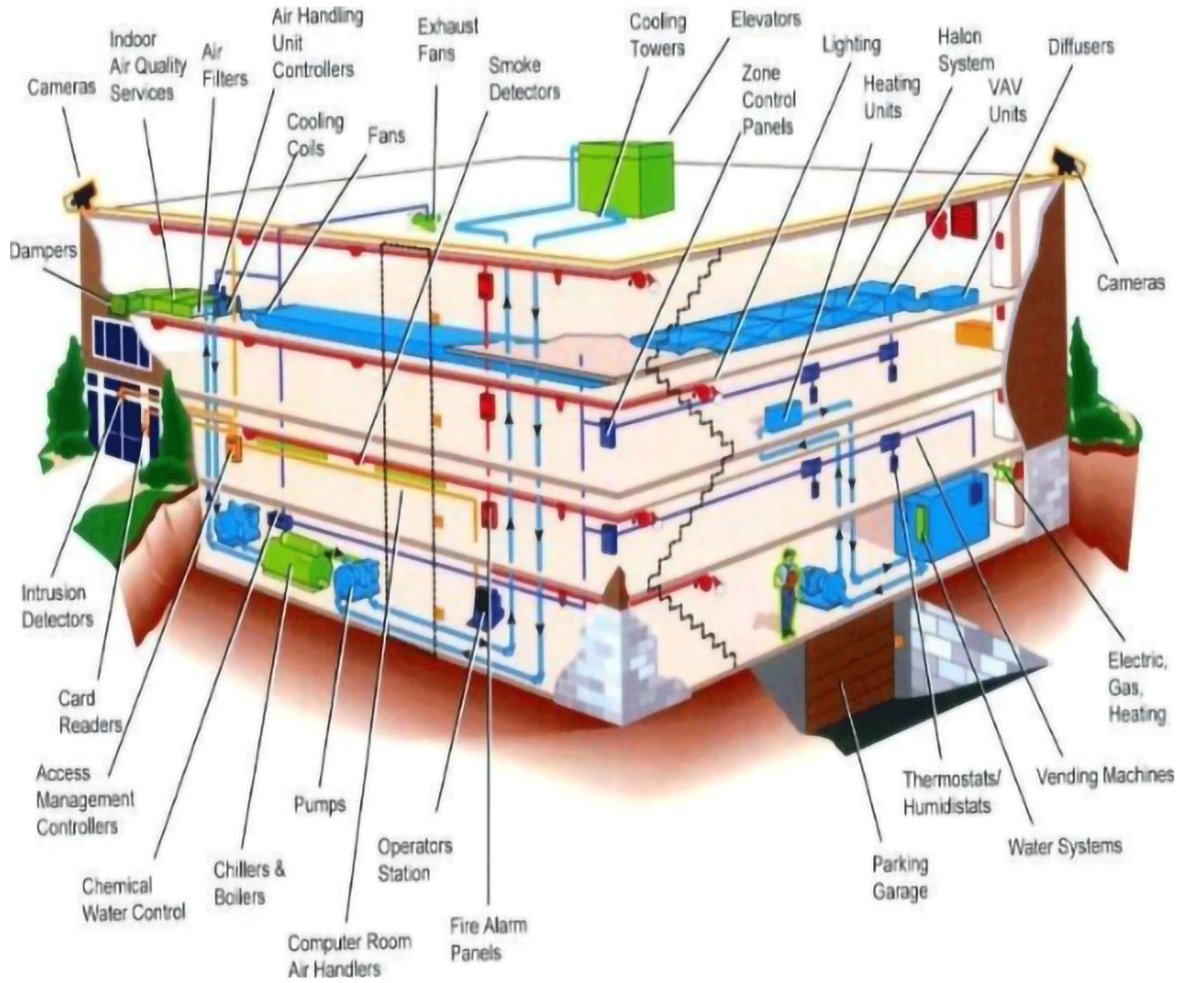
APPENDIX 2: SMART STREET LAMPS

Streetlights could carry a multitude of roles for the Smart City. Amongst the many functions they could perform are:

- Weather station – wind speed and direction, rainfall gauge, temperature, humidity, barometric pressure
- Flood monitor
- Mesh wireless access point
- Traffic monitor
- Gunshot monitoring
- Cry for help monitoring
- Cross walk monitoring
- Citizen tracking (what smartphones are nearby...)
- Spectral output/intensity control/power load/ based on time of night, RF field intensity measurement
- Information display



APPENDIX 3:
SMART BUILDINGS



<https://www.slideshare.net/SaNaLKuMaR17/iot-for-smart-city-59762552>

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